REMARKS

This amendment is responsive to the *Final* Office Action of August 20, 2008. Reconsideration and allowance of claims 1-6 and 8-15 are requested.

The Office Action

Claims 1-6 and 11-15 stand rejected under 35 U.S.C. § 102 as being anticipated by Shen (Differential Volume Rendering: A Fast Volume Visualization Technique For Flow Animation).

Claims 8 and 9 stand rejected under 35 U.S.C. § 103 as being unpatentable over Shen in view of Brandl (US 6,450,962).

Claim 10 stands rejected under 35 U.S.C. § 103 as being unpatentable over Shen in view of Goto (US 2004/00056658).

Background

Although Shen and the present application are both looking to accelerate rendering a series of cine images of a moving object, they do so with very different methods. Both Shen and the present application disclose receiving a first volume image which can be conceptualized as a three dimensional cubic array of first values. The first volume image is disclosed as being divided into an array of first voxels, each of which can be envisioned as the cube which is bounded on each of its 8 vertices by one of the first values. As indicated on page 182 of Shen, right column, second paragraph, each cubic volume or voxel is defined by the eight values on its eight vertices. The voxels which are relevant to a visualization, such as the voxels lying on the surface of the heart facing an image plane are determined and projected or ray cast onto the two dimensional image plane to derive a first two dimensional image. Ray casting each of the pixels of the two dimensional image into the volume image and determining which voxel corresponds to the surface of the heart is a time-consuming operation as explained in detail on pages 182 and 183 of Shen. Accordingly, both the present application and Shen wish to avoid repeating this entire process on a second volume image which is generated a short time interval after the first volume image. However, both use very different techniques for reducing the number of calculations.

The present application discloses that the voxels on the surface of the heart (or other region of interest) in the first image are identified and stored. Further, voxels which neighbor the voxels on the surface of the heart are also identified and stored. This expansion or dilation to add neighboring voxels may be performed based on a motion model which predicts which way the surface of the heart will move and identified neighbors in that direction. Alternately, all voxels within a selected radius of one of the voxels that was identified and stored are added as neighboring voxels. Then the ray casting operation is performed only with respect to the corresponding voxels of the second image volume. In this manner, only a very few voxels of the second volume image need to be ray cast to define a second two dimensional image.

Shen takes a completely different approach. Shen does not make or store a list of the voxels of the first image which lie on the surface of the heart (or active region of interest). Rather, Shen subtracts the first and second volume images (FIG. 1). Tissue which has not moved should have the same value in both the first and second images, hence those values in the differential image file will zero. Those image values which represent tissue which has moved, will be non-zero. Shen then performs the ray casting operation only on the voxels of the second voxel image on the voxels that moved, i.e., on ones bounded on one or more of its eight vertices by an image value which changed between the first and second volume images. In this manner, Shen only ray casts based on voxels which actually moved.

Briefly summarized, Shen ray casts only based on those voxels in the second and subsequent images which actually moved from the preceding volume image. But Shen must perform a time-consuming subtraction of each volume image and its preceding volume image to identify which voxels moved. The present application saves this computationally intensive subtraction of two volume images. Instead, the present application ray casts the voxels of the second volume image based on the voxels of the first volume image (and their neighbors) which contributed to the first 2D image. The ray casting operation is made simpler and less computationally intensive because the voxels between the image plane and the closest of the neighboring voxels can be ignored in the ray casting operation. In this manner, the present application and Shen both accelerate the generation of 2D images from subsequent volume images, but the present application is less computationally intensive, i.e., faster and is less sensitive to patient motion.

This discussion is to assist the Examiner in understanding Shen and the present application. This discussion is for background and is not intended to argue patentability or meaning of the present claims and should not be construed as limiting the claims in any way. Rather, the claims are discussed below.

The Claims Are Not Anticipated By Shen

Claim 1, Section (d), calls for determining the values of the second volume image that are relevant to the visualization from the values that are associated with the previously stored first voxels or their neighbors, i.e., the first volume image voxels from which the first 2D image was derived. Shen does not determine the values of the second volume image that are relevant based on the relevant voxels of the first volume image or on neighbors of the relevant voxels of the first volume image. To the contrary, Shen subtracts the first and second volume images to determine which voxels have changed in the second volume image. It is through this subtraction of the first and second volume images that Shen determines his relevant values of the second volume image. Shen does not determine the relevant values of the second volume image based on the relevant voxels of the first volume image. By determining the relevant values of the second volume image based on the values of the relevant voxels of the first volume image, the present application saves subtracting the first and second volume images which, in a typical diagnostic image, is a very large number of subtraction operations. Moreover, Shen's subtraction of the first and second volume images is very susceptible to degradation due to image artifacts or to patient motion. If the patient should shift or move the imaged body portion by so much as a pixel, subtracting the first and second volume images will identify a large number of values of the second image as relevant including many that are not. By contrast, the present technique of identifying the relevant values of the second volume image based on the relevant voxels of the first volume image is relatively immune to and can compensate for small amounts of patient motion.

The "Pixel Positions Calculation" section of Shen referenced by the Examiner does not address determining which values of the second volume image are considered to be the claimed relevant values. Again, Shen determines the relevant values of the second volume image by subtracting the first and second volume images as set forth in the "Differential Volume Rendering" section on page 181.

The "Pixel Positions Calculation" section of Shen is describing interpolation to make the two dimensional image more accurate. The two dimensional image can be visualized as a two dimensional square array of pixels. When one ray casts to project a voxel (or more accurately the values on each of its eight vertices) of the volume image onto the two dimensional image plane, chances are that the projection will not strike one of the pixels cleanly. More specifically, in the second paragraph of the right hand column of page 182, Shen proposes to ray cast the second volume values associated with each of the eight vertices of a voxel back onto the 2D image plane. Most of these projected vertices will strike the image plane at a point between pixels of the 2D image, more specifically there will typically be four pixels which neighbor where each ray strikes. The portion of the third paragraph of the right hand column of page 8 referenced by the Examiner describes how to interpolate the volume value associated with each ray among the four closest 2D image pixels.

Thus, the section Shen referenced by the Examiner relates to interpolation for a more accurate 2D image and does not relate to determining which values of the second image volume are the relevant values for use in deriving the second two dimensional image.

Second (d) of claim 1 calls for determining which values of the second volume image are the relevant values by looking to the voxels and corresponding values of the first volume image which were used to generate the first 2D image. By contrast, Shen determines which values of the second volume image are the relevant values by subtracting the first and second volume images to see which values change see the "Differential Volume Rendering" section of Shen on page 181. The "Pixel Positions Calculation" section referenced by the Examiner in conjunction with Section (d) does not relate to determining which values of the second volume image are the relevant values. Rather, once values of a volume image are recast onto a 2D image plane, this section relates to how those values should be interpolated to make the 2D image more accurate.

Because Section (d) of claim 1 relates to determining which values of the second volume image are relevant and the "Pixel Position Calculation" section of Shen relates to interpolation (it is the "Differential Volume Rendering" section of Shen which relates to determining which values of the second volume image are

relevant), it is submitted that Shen does not anticipate claims 1 and claims 2-6, 12, and 13 dependent therefrom.

Claim 2 calls for determining the relevant values of the second volume image based on neighboring voxels to the voxels from which the first 2D image was derived, which neighboring model voxels are defined by a motion model. Note that claim 2 calls for determining the relevant values of the second volume image based on a motion model. By contrast, in the Examiner's discussion of paragraph 8 on page 5 of the Office Action, the Examiner is deriving a motion model based on changes between the first and second 2D image. Stated another way, claim 2 calls for generating the second 2D image using the motion model; whereas, the Examiner proposes using the second 2D image to generate the motion model. Accordingly, it is submitted that claim 2 is clearly not anticipated by Shen.

Claim 11 calls for a second determining code segment for determining relevant values of the second volume image from values which are associated with the voxels or their neighbors of the first image that were used to derive the first 2D image. Rather than looking to the voxels of the first volume image to determine the values of the second volume image that are relevant, in the "Differential Volume Rendering" section Shen calls for subtracting the first and second volume images. The portion of the "Pixel Positions Calculation" section referenced by the Examiner relates to interpolating the ray cast values for a more accurate two dimensional image and does not relate to determining the relevant values of the second volume image.

Claim 14 calls for an image processor which determines the values of a second volume image that are relevant from the values associated with the voxels of the first volume image from which the first 2D image was derived. The relevant values are the values that are associated with the voxels from which the second 2D image is derived. Shen does not determine the relevant voxel values based on the voxels of the first image that were used to generate the first 2D image. Rather, Shen determines which values of the second image are relevant by subtracting the first and second images to see which values change. The "Pixel Positions Calculation" section of Shen relates to interpolation to make each derived 2D image more accurate.

Because Shen teaches against determining which values of the second volume image are relevant based on the voxels of the first volume image that were used to generate the first 2D image in favor of determining which values of the second volume element are relevant by subtracting the first and second volume

images, it is submitted that claim 14 and claims 8-10 and 15 dependent therefrom are not anticipated by Shen.

CONCLUSION

For the reasons set forth above, it is submitted that claims 1-6 and 8-15 are not anticipated by and distinguish patentably over Shen and the other references of record. An early allowance of all claims is requested.

Respectfully submitted,

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